

The Viewsonic P817 21 inch monitor (20" viewable area; the selling price is \$1600) is a color monitor with image quality and features that make it an excellent candidate display device for NIMA Imagery Exploitation Capability workstations. Based on results of our evaluation, NIDL certifies the Viewsonic P817 color monitor as being suitable for IEC workstations. NIDL rates this color monitor as a "B" (meets IEC requirements) for the Image Analyst and Cartographer applications. The "B" ratings, rather than "A", results from a slightly high halation value, and from a somewhat low, but typical of color monitors, stereo extinction ratio. In a light ambient, the monitor is calculated to achieve 158:1 dynamic range with 3 fc illumination, and 60:1 with 10 fc illumination falling onto the screen. NIDL evaluated the Sun/Sony 24 inch color monitor, gave it an "A" for its performance, and recommended its use for imagery analysts. We based this recommendation on its measured performance, analysts' preference for the 24 inch size with its greater area, and on its reliability. The Viewsonic P817 monitor is a very good color monitor, but the 24 inch Sony performs better in a number of areas.

## **Evaluation of the Viewsonic P817 4 x 3 Aspect Ratio, 21-Inch Diagonal Color CRT Monitor**

### **National Information Display Laboratory**

**P. O. Box 8619**

**Princeton, NJ 08543-8619**

**Tel: (609) 951-0150**

**Fax: (609) 734-2313**

**e-mail: [nidl@nidl.org](mailto:nidl@nidl.org)**

**Publication No. 730080400-103**

**May 22, 2000**

#### **NOTICE:**

This report was prepared by the National Information Display Laboratory (NIDL) at the Sarnoff Corporation. Neither the NIDL nor any person acting on their behalf:

- A. Makes any warranty or representation, expressed or implied, with respect to the use of any information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report is free from infringement of any third party rights; or
- B. Makes any endorsement of any of the products reported on herein; or
- C. Assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method, or process disclosed in this report.

Report Documentation Page		
<b>Report Date</b> 22 May 2000	<b>Report Type</b> N/A	<b>Dates Covered (from... to)</b> -
<b>Title and Subtitle</b> Evaluation of the Viewsonic P817 4 x 3 Aspect Ratio, 21-Inch Diagonal Color CRT Monitor	<b>Contract Number</b>	
	<b>Grant Number</b>	
	<b>Program Element Number</b>	
<b>Author(s)</b>	<b>Project Number</b>	
	<b>Task Number</b>	
	<b>Work Unit Number</b>	
<b>Performing Organization Name(s) and Address(es)</b> National Information Display Laboratory P.O. Box 8619 Princeton, NJ 08543-8619	<b>Performing Organization Report Number</b>	
<b>Sponsoring/Monitoring Agency Name(s) and Address(es)</b>	<b>Sponsor/Monitor's Acronym(s)</b>	
	<b>Sponsor/Monitor's Report Number(s)</b>	
<b>Distribution/Availability Statement</b> Approved for public release, distribution unlimited		
<b>Supplementary Notes</b> Per conversation with Ronald Enstrom this document is public release, The original document contains color images.		
<b>Abstract</b>		
<b>Subject Terms</b>		
<b>Report Classification</b> unclassified	<b>Classification of this page</b> unclassified	
<b>Classification of Abstract</b> unclassified	<b>Limitation of Abstract</b> UU	
<b>Number of Pages</b> 42		

## CONTENTS

<b>NIDL IEC Monitor Certification Report .....</b>	<b>iii</b>
Evaluation Datasheet .....	iv
<b>Section I INTRODUCTION .....</b>	<b>1</b>
I.1 The Viewsonic P817 Color CRT Monitor .....	2
I.2. Initial Monitor Set Up .....	3
I.3. Equipment .....	3
<b>Section II PHOTOMETRIC MEASUREMENTS.....</b>	<b>4</b>
II.1. Dynamic range and Screen Reflectance .....	4
II.2. Maximum Luminance (Lmax) .....	6
II.3. Luminance (Lmax) and Color Uniformity .....	7
II.4. Halation .....	9
II.5. Color Temperature .....	11
II.6. Bit Depth .....	12
II.8. Luminance Step Response .....	16
II.9. Addressability .....	17
II.10. Pixel Aspect Ratio .....	18
II.11. Screen Size (Viewable Active Image) .....	18
II.12. Contrast Modulation .....	20
II.13. Pixel Density .....	22
II.14. Moire .....	23
II.15. Straightness .....	24
II.16. Refresh Rate .....	27
II.17. Extinction Ratio .....	28
II.18. Linearity .....	31
II.19. Jitter/Swim/Drift .....	33
II.20 Warmup Period .....	35

## NIDL IEC Monitor Certification Report

### The Viewsonic P817 Color CRT Monitor

#### FINAL GRADES

**Monoscopic Mode: B**

**Stereoscopic Mode: B**

**A=Substantially exceeds IEC Requirements; B= Meets IEC Requirements; C=Nearly meets IEC Requirements; F=Fails to meet IEC Requirements in a substantial way**

The Viewsonic P817 21 inch monitor (20" viewable area; the selling price is \$1600) is a color monitor with image quality and features that make it an excellent candidate display device for NIMA Imagery Exploitation Capability workstations. Based on results of our evaluation, NIDL certifies the Viewsonic P817 color monitor as being suitable for IEC workstations. NIDL rates this color monitor as a "B" (meets IEC requirements) for the Image Analyst and Cartographer applications. The "B" ratings, rather than "A", results from a slightly high halation value, and from a somewhat low, but typical of color monitors, stereo extinction ratio. In a light ambient, the monitor is calculated to achieve 158:1 dynamic range with 3 fc illumination, and 60:1 with 10 fc illumination falling onto the screen. NIDL evaluated the Sun/Sony 24 inch color monitor, gave it an "A" for its performance, and recommended its use for imagery analysts. We based this recommendation on its measured performance, analysts' preference for the 24 inch size with its greater area, and on its reliability. The Viewsonic P817 monitor is a very good color monitor, but the 24 inch Sony performs better in a number of areas but at a somewhat higher price.

The Viewsonic P817 is a versatile color monitor for demanding display applications. This monitor is an OEM product of the well-regarded Viewsonic Professional series of monitors that have been on the market for several years. The CRT has a 0.26 mm dot-trio pitch (0.22 mm in the horizontal dimension). The tube is 90° deflection (20 inch deep), so it is not as shallow as the Hitachi CM814U monitor (16 inch deep). The horizontal and vertical scan rates are 30 to 130 kHz and 50 to 180 Hz, respectively. These values correspond to higher performance compared to other color monitors tested. The reliability of the Viewsonic P817 monitor is not known; Stephen Viggiano at Lockheed Martin will probe for field experience with the Viewsonic P815 monitor.

The 4:3 aspect ratio and the 21 inch diagonal give the analyst a large working area surpassed only by 24-inch wide-screen monitors. According to the manufacturer, the Viewsonic P817 monitor will display up to 2048 x 1536 pixels. The monitor meets all critical IEC requirements in the monoscopic mode except the halation of 4.3% is somewhat higher than the 3.5% required in the IEC specification. In the stereo mode, the 10:1 extinction ratio determined with a NuVision stereo panel and passive glasses is less than the 15:1 required in the IEC specification. However its value is in line with other color monitors. Stereo performance will be better with a monochrome display, where values greater than 20:1 are measured. The horizontal scan frequency is high enough to support stereo image formation.

The manufacturer lists the maximum addressability as 2048 x 1536 pixels. However, the phosphor pitch of 0.22 mm horizontal (0.26 mm diagonal) limits the number of red, green and blue triads that can be addressed to less than 2048 pixels in the horizontal direction. As evaluated, NIDL's measurements for viewable image size of 15.656 x 11.705 inches indicate a maximum of 1808 pixels in the horizontal direction based on the horizontal phosphor pitch.

The Viewsonic P817 monitor is described on the website, <http://www.viewsonic.com>. Color monitors are more difficult to evaluate and their performance may not compare to monochrome monitors. But, they do give the analyst the additional dimension of color for their tasks. Color monitors have three electron guns (R, G, and B) to focus and converge. They also have a perforated steel shadow mask that separates the colors on the screen and this adds complexity. Color lines formed on the phosphor screen may not be as narrow as for a monochrome, single electron gun-formed spot. The color monitor's light output may not be as high. The IEC monitor specifications for color monitors reflect this difference, and are less stringent than for a monochrome monitor. NIDL evaluated three monochrome monitors recently and found that they easily passed all the monoscopic and stereoscopic specifications; we recommended all three. Color monitors have a harder time passing all the less stringent IEC color monitor specifications and yet there are very good COTS color monitors on the market. Imagery analysts at a number of organizations do their analyses on color monitors. Thus, we are somewhat flexible in our grading for color monitors, since perfection is more difficult to achieve.

NIDL evaluated the Sun/Sony 24 inch color monitor, gave it an "A" for its performance, and recommended its use for imagery analysts. We based this recommendation on its measured performance, analysts' preference for the 24 inch diagonal, the 16:10 format with its greater area, and on its reliability. The Viewsonic P817 monitor is a very good color monitor, but the 24 inch Sony performs better in the following areas:

- ◆ Luminance, 21% higher for Sony
- ◆ Uniformity, 12 % better for Sony
- ◆ Halation, 12% lower for Sony
- ◆ Contrast modulation, Zone A (Sony nearly twice as high as the Viewsonic)
- ◆ Contrast modulation, Zone B (Sony 33% higher than the Viewsonic)
- ◆ Linearity, about the same for both monitors
- ◆ Warm-up, Viewsonic about twice as fast as the Sony
- ◆ Vertical refresh rate in stereo is better for the Viewsonic, 120 Hz versus 92 Hz for the Sony
- ◆ Extinction ratio in stereo, 29% better for Sony compared to Viewsonic

In ambient lighting with 3 or 10 fc falling onto the face of the monitor, both perform about the same.

The dimensions for the Viewsonic are: 19.5 inch Wide x 19.3 inch High x 20.6 inch Deep x 66 pounds. The 24 inch Sony is 22.8 inch Wide x 19.8 inch High x 21.6 inch Deep x 90 pounds.

Thus price, \$2500 for the 24 inch Sun/Sony versus about \$1600 for the 21 inch Viewsonic P817 may be a deciding factor in the choice of color monitor in addition to performance.

## Evaluation Datasheet

Mode	IEC Requirement	Measured Performance		Compliance
MONOSCOPIC				
Addressability	1024 x 1024 min.	1280 x 1024	1600 x 1200	pass
Dynamic Range	24.7dB	25.9	25.6 dB	pass
Luminance (Lmin)	0.1 fL min. ± 4%	0.1	0.1	pass
Luminance (Lmax)	30 fL ± 4%	38.5	32.8	pass
Uniformity (Lmax)	20% max.	Not measured	17.8%	pass
Halation	3.5% max.	Not measured	4.3%	fail
Color Temp	6500 to 9300 K	Not measured	6808 K	pass
Reflectance	Not specified	Not measured	4.6%	
Bit Depth	8-bit± 5 counts	Not measured	8-bit	pass
Step Response	No visible ringing	Not measured	Clean	pass
Uniformity (Chromaticity)	0.010 delta u'v' max. ± 0.005 Δ u'v'	Not measured	0.006 delta u'v'	pass
Pixel aspect ratio	Square H = V± 6%	Set to square	Set to square	pass
Screen size, viewable diagonal	17.5 to 24 inches ± 2 mm	20 ins.	19.5 ins.	pass
Cm, Zone A	25% min.	Not measured	29%	pass
Cm, Zone B	20% min.	Not measured	40%	pass
Pixel density	72 ppi min.	93.4 ppi	102.3 ppi	pass
Moiré, phosphor-to-pixel spacing	1.0 max	0.81	0.89	pass
Straightness	0.5% max ± 0.05 mm	Not measured	0.45%	pass
Linearity	1.0% max ± 0.05 mm	Not measured	0.88%	pass
Jitter	2 ± 2 mils max.	Not measured	1.9 mils	pass
Swim, Drift	5 ± 2 mils max.	Not measured	3.0 mils	pass
Warm-up time, Lmin to +/- 50%	30 mins. Max ± 0.5 minute	Not measured	less than 1 min.	pass
Warm-up time, Lmin to +/- 10%	60 mins. Max ± 0.5 minute	Not measured	49 mins.	pass
Refresh	72 ±1 Hz min. 60 ±1 Hz absolute	Set to 72 Hz	Set to 72 Hz	pass
STEREOSCOPIC				
Addressability	1024 x 1024 min.	1024 x 2048 (I)		pass
Lmin	Not specified	0.097 fL		
Lmax	6 fL min ± 4%	6.04 fL		pass
Dynamic range	17.7 dB min	17.9 dB		pass
Uniformity (Chromaticity)	0.02 delta u'v' max ± 0.005 Δ u'v'	0.008 delta u'v'		pass
Refresh rate	60 Hz per eye, min	60 Hz, per eye		pass
Extinction Ratio	15:1 min	10.0:1		fail
AMBIENT LIGHTING				
Dynamic Range 22 dB (158:1)	N/A		3 fc	
Dynamic Range 17.8 dB (60:1)	N/A		10 fc	

(I) denotes interlaced scanning

(n) denotes Nuvision LCD shutter panel



## Section I INTRODUCTION

The National Information Display Laboratory (NIDL) was established in 1990 to bring together technology providers - commercial and academic leaders in advanced display hardware, softcopy information processing tools, and information collaboration and communications techniques - with government users. The Sarnoff Corporation in Princeton, New Jersey, a world research leader in high-definition digital TV, advanced displays, computing and electronics, hosts the NIDL.

The present study evaluates a production unit of the Viewsonic P817, color CRT high-resolution display monitor. This report is intended for both technical users, such as system integrators, monitor designers, and monitor evaluators, and non-technical users, such as image analysts, software developers, or other users unfamiliar with detailed monitor technology.

The IEC requirements, procedures and calibrations used in the measurements are detailed in the following:

- *NIDL Publication No. 0201099-091, Request for Evaluation Monitors for the National Imagery & Mapping Agency (NIMA) Integrated Exploitation Capability (IEC), August 25, 1999.*

Two companion documents that describe how the measurements are made are available from the NIDL and the Defense Technology Information Center at <http://www.dtic.mil>:

- *NIDL Publication No. 171795-036 Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20 Part 1: Monochrome CRT Monitor Performance Draft Version 2.0. (ADA353605)*
- *NIDL Publication No. 171795-037 Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20 Part 2: Color CRT Monitor Performance Draft Version 2.0. (ADA341357)*

Other procedures are found in a recently approved standard available from the Video Electronics Standards Association (VESA) at <http://www.vesa.org>:

- *VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998.*  
*Publication No. 0201099-091, Request for Evaluation Monitors for the National Imagery & Mapping Agency (NIMA) Integrated Exploitation Capability (IEC), August 25, 1999.*

The IEC workstation provides the capability to display image and other geospatial data on either monochrome or color monitors, or a combination of both. Either of these monitors may be required to support stereoscopic viewing. Selection and configuration of these monitors will be made in accordance with mission needs for each site. NIMA users will select from monitors included on the NIMA-approved Certified Monitor List compiled by the NIDL. The color and monochrome, monoscopic and stereoscopic, monitor requirements are listed in the Evaluation Datasheet.



## I.1 The Viewsonic P817 Color CRT Monitor

### Viewsonic's Specifications

According to Viewsonic, the specifications for the Viewsonic P817 monitor are:

<b>CRT</b>	<b>Type</b>	21" (20.0" diagonal viewable area) 0.22mm Hor. dot pitch, 90 deg; deflection (0.26mm Diag.)
	<b>Phosphor</b>	B22 medium-short persistence
	<b>Glass Surface</b>	Tint (TM=48%), anti-static, ARAG screen treatment
<b>INPUT SIGNAL</b>	<b>Video</b>	RGB Analog (0.7V/1.0Vp-p, 75 ohms)
	<b>Sync</b>	H/V separate (TTL), composite, sync-on-green
	<b>Frequency</b>	F <sub>H</sub> :30-137kHz, F <sub>V</sub> :50-180Hz
<b>COMPATIBILITY</b>	<b>PC</b>	IBM® XT, AT, 386, 486, Pentium®, PS/2 and compatibles (from VGA up to 2,048 x 1,536 @ 85 Hz)
	<b>Mac®*</b>	Power Mac™ (up to 1600 x 1200 @ 108 Hz)
	<b>Other**</b>	Most workstations
<b>CONNECTOR</b>	<b>Signal</b>	BNC (x5) and 15-pin mini D-sub
	<b>Power</b>	3-pin plug (IEC320)
<b>POWER</b>	<b>Voltage</b>	AC 90-264V 50/60 (+/-3)Hz
	<b>Consumption</b>	150W (typ)
<b>USER CONTROLS</b>	<b>Basic</b>	Power on/off, Key-1, Key-2, down, up
	<b>OnView®</b>	Contrast, brightness, H/V-size, H/V-position, pincushion, pin- balance, trapezoid, parallelogram, top/bottom hook, top/bottom hook balance, rotation, ViewMeter®, purity, H/V-convergence, H/V-focus, View Match® color, input select, OSD position, moiré, degauss, language, exit, recall
<b>VIDEO INPUT</b>	<b>Bandwidth</b>	360MHz (typ)
<b>USB</b>	<b>Up/Down Stream</b>	1 connection/ 4 connections
<b>MISCONVERGENCE</b>		0.24mm at center, 0.32mm at corner
<b>DISPLAY AREA</b> (Dependent upon signal timing used)	<b>Factory Setting</b>	380mm (H) x 285mm (V)
	<b>Maximum Scan</b>	410mm (H) x 308mm (V)
<b>OPERATING CONDITION</b>	<b>Temperature</b>	32degF to 95degF (0degC to 35degC)
	<b>Humidity</b>	5% to 95% (non-condensing)
<b>DIMENSIONS</b>	<b>Physical</b>	496mm (W) x 491mm (H) x 524mm (D) (19.5" x 19.3" x 20.6")
<b>WEIGHT</b>	<b>Net</b>	30Kg (66.2 lbs.)
<b>OTHER</b>		DDC1, DDC2B
<b>REGULATIONS</b>		UL, CSA, TUV/GS, MPR-II, ISO9241-3, DHHS, FCC-B, DOC- B, EM/CE. TCO '99, BCIQ, CCTB, PTB, NEMKO, DEMKO, FEMKO, SEMKO, B-Mark, VCCI-II, C-Tick, S-Mark
<b>POWER MANAGEMENT</b>		Meets Energy Star®, VESA® DPMS™, Energy 2000 and TCO '99 standards
<b>WARRANTY</b>		Three year limited warranty on CRT, parts and labor 48 hour Express Exchange® Service option available

## I.2. Initial Monitor Set Up

*Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5, p 5.*

All measurements will be made with the display commanded through a laboratory grade programmable test pattern generator. The system will be operated in at least a 24 bit mode (as opposed to a lesser or pseudo-color mode) for color and at least 8 bits for monochrome. As a first step, refresh rate should be measured and verified to be at least 72 Hz. The screen should then be commanded to full addressability and Lmin set to 0.1 fL. Lmax should be measured at screen center with color temperature between D65 and D93 allowable and any operator adjustment of gain allowable. If a value >35fL is not achieved (>30 fL for color), addressability should be lowered. For a nominal 1200 by 1600 addressability, addressability should be lowered to 1280 by 1024 or to 1024 by 1024. For a nominal 2048 by 2560 addressability, addressabilities of 1200 x 1600 and 1024 x 1024 can be evaluated if the desired Lmax is not achieved at full addressability.

## I.3. Equipment

*Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 2.0, page 3.*

The procedures described in this report should be carried out in a darkened environment such that the stray luminance diffusely reflected by the screen in the absence of electron-beam excitation is less than 0.003 cd/m<sup>2</sup> (1mfL).

Instruments used in these measurements included:

- Quantum Data 8701 400 MHz programmable test pattern signal generator
- Quantum Data 903 250 MHz programmable test pattern signal generator
- Photo Research SpectraScan PR-650 spectroradiometer
- Photo Research SpectraScan PR-704 spectroradiometer
- Minolta LS-100 Photometer
- Minolta CA-100 Colorimeter
- Graseby S370 Illuminance Meter
- Microvision Superspot 100 Display Characterization System which included OM-1 optic module (Two Dimensional photodiode linear array device, projected element size at screen set to 1.3 mils with photopic filter) and. Spotseeker 4-Axis Positioner

Stereoscopic-mode measurements were made using the following commercially-available stereo products:

- Nuvision 19-inch LCD shutter with passive polarized eyeglasses.

## Section II PHOTOMETRIC MEASUREMENTS

### II.1. Dynamic range and Screen Reflectance

*References: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.6, p 6.*

*VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 199, Section 308-1.*

*Full screen white-to-black dynamic range in a dark room in 1280 x 1024 format is 25.9dB and in 1600 x 1200 format is 25.2 dB. It is less than 22 dB (the absolute threshold for IEC) in 3 fc diffuse ambient illumination.*

**Objective:** Measure the photometric output (luminance vs. input command level) at Lmax and Lmin in both dark room and illuminated ambient conditions.

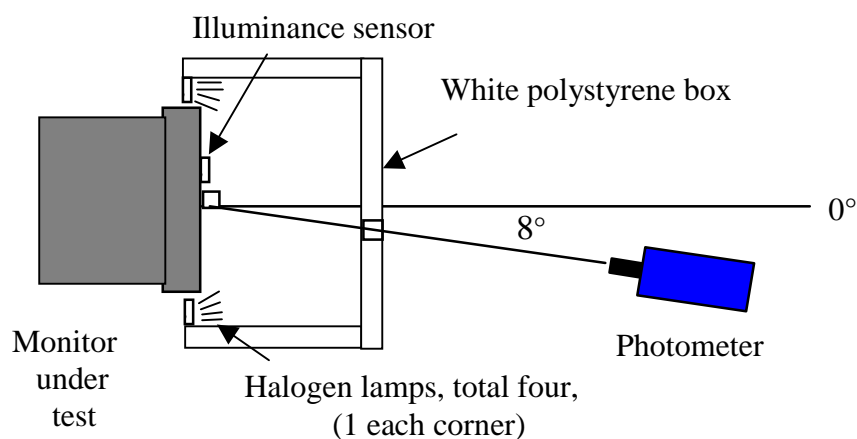
**Equipment:** Photometer, Integrating Hemisphere Light Source or equivalent

**Procedure:** Luminance at center of screen is measured for input counts of 0 and Max Count. Test targets are full screen (flat fields) where full screen is defined addressability. Set Lmin to 0.1 fL. For color monitors, set color temperature between D<sub>65</sub> to D<sub>93</sub>. Measure Lmax.

This procedure applies when intended ambient light level measured at the display is 2fc or less. For conditions of higher ambient light level, Lmin and Lmax should be measured at some nominal intended ambient light level (e.g., 18-20 fc for normal office lighting with no shielding). This requires use of a remote spot photometer following procedures outlined in reference 2, paragraph 308-2. This will at best be only an approximation since specular reflections will not be captured. A Lmin > 0.1 fL may be required to meet grayscale visibility requirements.

According to the VESA directed hemispherical reflectance (DHR) measurement method, total combined reflections due to specular, haze and diffuse components of reflection arising from uniform diffuse illumination are simultaneously quantified as a fraction of the reflectance of a perfect white diffuse reflector using the set up depicted in figure II.1-1. Total reflectance was calculated from measured luminances reflected by the screen (display turned off) when uniformly illuminated by an integrating hemisphere simulated using a polystyrene ice box. Luminance is measured using a spot photometer with 1° measurement field and an illuminance sensor as depicted in Figure II.1-1. The measured values and calculated reflectances are given in Table II.1-1.

**Data:** Define dynamic range by:  $DR = 10 \log(L_{max}/L_{min})$



- Top View -

**Figure II.1-1.** Test setup according to VESA FPDM procedures for measuring total reflectance of screen.

**Table II.1-1. Directed Hemispherical Reflectance of Faceplate**

VESA ambient contrast illuminance source (polystyrene box)

Ambient Illuminance	20.5 fc
Reflected Luminance	0.95 fL
Faceplate Reflectance	4.6 %

Ambient dynamic ranges of full screen white-to-black given in Table II.1-2 were computed for various levels of diffuse ambient lighting using the measured value for DHR and the darkroom dynamic range measurements. Full screen white-to-black dynamic range decreases from 25.9 dB in a dark room to 22 dB (the absolute threshold for IEC) in 3 fc diffuse ambient illumination.

**Table II.1-2. Dynamic Range in Dark and Illuminated Rooms**

Effect of ambient lighting on dynamic range is calculated by multiplying the measured CRT faceplate reflectivity times the ambient illumination measured at the CRT in foot candles added to the minimum screen luminance,  $L_{min}$ , where  $L_{min} = 0.1 \text{ fL}$ .

Ambient Illumination	Displayed Addressable Format	
	1280 x 1024	1600 x 1200
0 fc (Dark Room)	25.9 dB	25.2 dB
1 fc	24.2 dB	23.5 dB
2 fc	23.0 dB	22.3 dB
3 fc	22.1 dB	21.4 dB
4 fc	21.3 dB	20.6 dB
5 fc	20.7 dB	20.0 dB
6 fc	20.1 dB	19.4 dB
7 fc	19.6 dB	18.9 dB
8 fc	19.2 dB	18.5 dB
9 fc	18.8 dB	18.1 dB
10 fc	18.4 dB	17.7 dB

## II.2. Maximum Luminance (Lmax)

*References: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.2, p 6.*

*The highest luminance for Lmax was 38.5 fL measured at screen center in 1280 x 1024 format. Lmax dropped to 32.8 fL in 1600 x 1200 format.*

Objective: Measure the maximum output display luminance.

Equipment: Photometer

Procedure: See dynamic range. Use the value of Lmax defined for the Dynamic Range measurement.

Data: The maximum output display luminance, Lmax, and associated CIE x, y chromaticity coordinates (CIE 1976) were measured using a hand-held colorimeter (Minolta CA-100). The correlated color temperature (CCT) computed from the measured CIE x, y chromaticity coordinates was within range specified by IEC (6500K and 9300K).

**Table II.2-1. Maximum Luminance and Color**

Color and luminance (in fL) for Full screen at 100% Lmax taken at screen center.

<u>Format</u>	<u>CCT</u>	<u>CIE x</u>	<u>CIE y</u>	<u>Luminance</u>
1280 x 1024	Not measured	Not measured	Not measured	38.5 fL
1600 x 1200	6808 K	0.310	0.313	32.8 fL

## II.3. Luminance ( $L_{\max}$ ) and Color Uniformity

*Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 4.4, p. 28.*

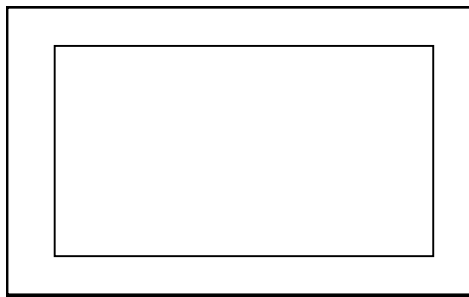
*Maximum luminance ( $L_{\max}$ ) varied by up to 17.8% across the screen. Chromaticity variations were less than 0.006  $\Delta u'v'$  units.*

**Objective:** Measure the variability of luminance and chromaticity coordinates of the white point at 100%  $L_{\max}$  only and as a function of spatial position. Variability of luminance impacts the total number of discriminable gray steps.

**Equipment:**

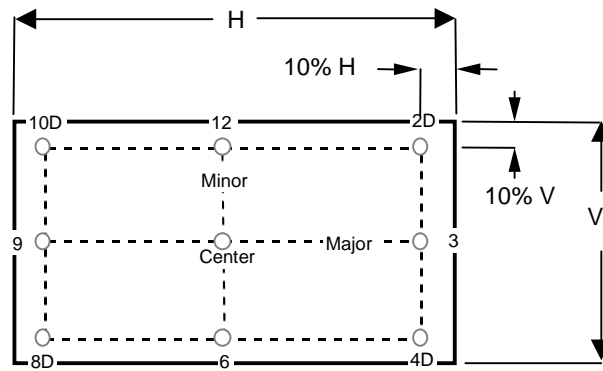
- Video generator
- Photometer
- Spectroradiometer or Colorimeter

**Test Pattern:** Full screen flat field with visible edges at  $L_{\min}$  as shown in Figure II.3-1.



*Full Screen Flat Field test pattern.*

**Figure II.3-1**



*Nine screen test locations.*

**Figure II.3-2**

**Procedure:** Investigate the temporal variation of luminance and the white point as a function of intensity by displaying a full flat field shown in Figure II.3-1 for video input count levels corresponding  $L_{\max}$ . Measure the luminance and C.I.E. color coordinates at center screen.

Investigate the temporal variation of luminance and the white point as a function of spatial position by repeating these measurements at each of the locations depicted in Figure II.3-2. Define color uniformity in terms of  $\Delta u'v'$ .

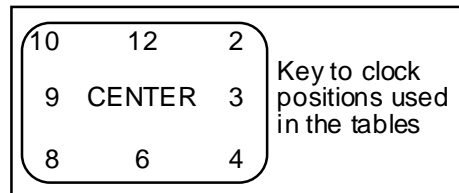
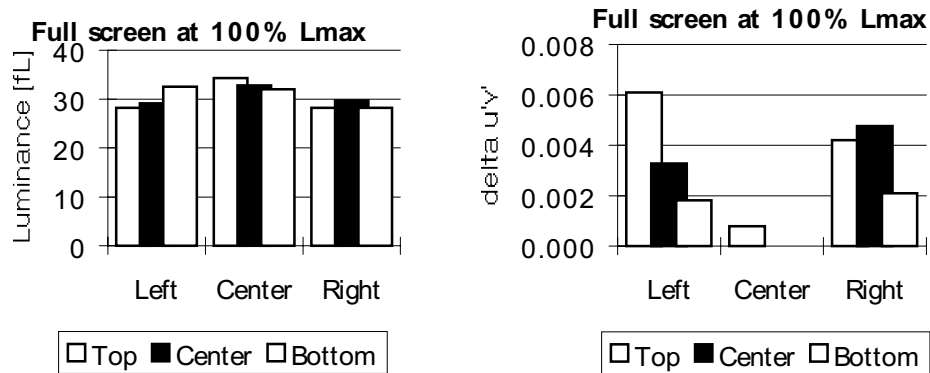
**Data:** Tabulate the luminance and 1931 C.I.E. chromaticity coordinates ( $x$ ,  $y$ ) or correlated color temperature of the white point at each of the nine locations depicted in Figure II.3-2. Additionally, note the location of any additional points that are measured along with the corresponding luminance values.

**Table II.3-1.Spatial Uniformity of Luminance and Color**

Color and luminance (in fL) for Full screen at 100% Lmax taken at nine screen positions.

**1600 x 1200**

<u>POSITION</u>	<u>CCT</u>	<u>CIE x</u>	<u>CIE y</u>	<u>L, fL</u>
center	6808	0.310	0.313	32.8
2	6878	0.310	0.307	28.2
3	6346	0.317	0.317	29.7
4	7028	0.307	0.311	28.2
6	6808	0.310	0.313	32.0
8	6766	0.311	0.311	32.5
9	6933	0.309	0.308	29.1
10	6224	0.319	0.318	28.2
12	6884	0.309	0.312	34.3

**1600 x 1200****Fig.II.3-3.** Spatial Uniformity of Luminance and Chromaticity.  
(Delta u'v' of 0.004 is just visible.)

## II.4. Halation

*Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 4.6, page 48.*

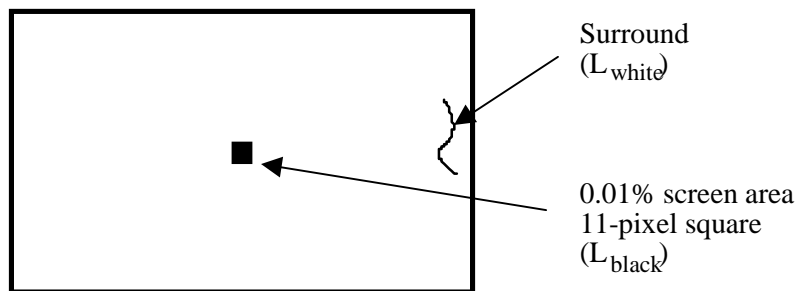
*Halation was 4.3 % +/- 0.3% on a small black patch surrounded by a large full white area.*

**Objective:** Measure the contribution of halation to contrast degradation. Halation is a phenomenon in which the luminance of a given region of the screen is increased by contributions from surrounding areas caused by light scattering within the phosphor layer and internal reflections inside the glass faceplate. The mechanisms that give rise to halation, and its detailed non-monotonic dependence on the distance along the screen between the source of illumination and the region being measured have been described by E. B. Gindele and S.L. Shaffer. The measurements specified below determine the percentage of light that is piped into the dark areas as a function of the extent of the surrounding light areas.

**Equipment:**

- Photometer
- Video generator

**Test Pattern:**



**Figure II.4-1** *Test pattern for measuring halation.*

**Procedure:** Note: The halation measurements require changing the setting of the BRIGHTNESS control and will perturb the values of  $L_{\max}$  and  $L_{\min}$  that are established during the initial monitor set-up. The halation measurements should therefore be made either first, before the monitor setup, or last, after all other photometric measurements have been completed.

Determine halation by measuring the luminance of a small square displayed at  $L_{\text{black}}$  (essentially zero) and at  $L_{\text{white}}$  when surrounded by a much larger square displayed at  $L_{\text{white}}$  (approximately 75%  $L_{\max}$ ).

Establish  $L_{\text{black}}$  by setting the display to cutoff. To set the display to cut-off, display a flat field using video input count level zero, and use a photometer to monitor the luminance at center screen. Vary the BRIGHTNESS control until the CRT beam is visually cut off, and confirm that the corresponding luminance ( $L_{\text{stray}}$ ) is essentially equal to zero. Fine tune the BRIGHTNESS control such that



CRT beam is just on the verge of being cut off. These measurements should be made with a photometer which is sensitive at low light levels (below  $L_{\min}$  of the display). Make no further adjustments or changes to the BRIGHTNESS control or the photometer measurement field.

Next, decrease the video input level to display a measured full-screen luminance of 75%  $L_{\max}$  measured at screen center. Record this luminance ( $L_{\text{white}}$ ).

The test target used in the halation measurements is a black ( $L_{\text{black}}$ ) square patch of width equal to 0.01% of the area of addressable screen, the interior square as shown in Figure II.4-1. The interior square patch is enclosed in a white ( $L_{\text{white}}$ ) background encompassing the remaining area of the image. The exterior surround will be displayed at 75%  $L_{\max}$  using the input count level for  $L_{\text{white}}$  as determined above. The interior square will be displayed at input digital count level zero.

Care must be taken during the luminance measurement to ensure that the photometer's measurement field is less than one-half the size of the interior square and is accurately positioned not to extend beyond the boundary of the interior square. The photometer should be checked for light scattering or lens flare effects which allow light from the surround to enter the photosensor. A black card with aperture equal to the measurement field (one-half the size of the interior black square) may be used to shield the photometer from the white exterior square while making measurements in the interior black square.

**Analysis:** Compute the percent halation for each test target configuration. Percent halation is defined as:

$$\% \text{ Halation} = L_{\text{black}} / (L_{\text{white}} - L_{\text{black}}) \times 100$$

Where,  $L_{\text{black}}$  = measured luminance of interior square displayed at  $L_{\text{black}}$  using input count level zero,  
 $L_{\text{white}}$  = measured luminance of interior square displayed at  $L_{\text{white}}$  using input count level determined to produce a full screen luminance of 75%  $L_{\max}$ .

**Data:** Table II.4-1 contains measured values of  $L_{\text{black}}$ ,  $L_{\text{white}}$  and percentage halation.

**Table II.4-1** Halation for 1600 x 1200 Addressability

	Reported Values	Range for 4% uncertainty
$L_{\text{black}}$	1.04 fL $\pm$ 4%	0.998 fL to 1.08 fL
$L_{\text{white}}$	24.3 fL $\pm$ 4%	23.3 fL to 25.3 fL
Halation	4.3% $\pm$ 0.3%	4.0 % to 4.6%

## II.5. Color Temperature

*Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 5.4, page 22.*

*The CCT of the measured white point lies within the boundaries accepted by IEC.*

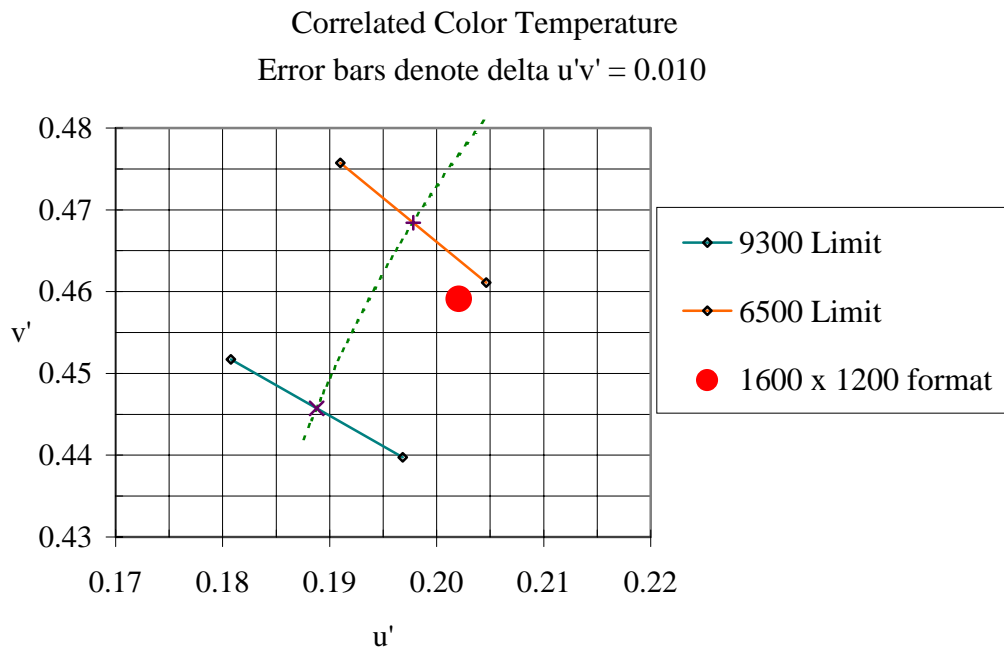
**Objective:** Insure measured screen white of a color monitor has a correlated color temperature (CCT) between 6500K and 9300K.

**Equipment:** Colorimeter

**Procedure:** Command screen to Lmax. Measure  $u'v'$  chromaticity coordinates (CIE 1976).

**Data:** Coordinates of screen white should be within 0.01  $\Delta u'v'$  of the corresponding CIE daylight, which is defined as follows: If the measured screen white has a CCT between 6500 and 9300 K, the corresponding daylight has the same CCT as the screen white. If the measured CCT is greater than 9300 K, the corresponding daylight is D93. If the measured CCT is less than 6500 K, the corresponding daylight is D65. The following equations were used to compute  $\Delta u'v'$  values listed in table II.5.1:

1. Compute the correlated color temperature (CCT) associated with (x, y) by the VESA/McCamy formula:  $CCT = 437 n^3 + 3601 n^2 + 6831 n + 5517$ , where  $n = (x - 0.3320) / (0.1858 - y)$ . [This is on p. 227 of the FPDM standard]
2. If  $CCT < 6500$ , replace CCT by 6500. If  $CCT > 9300$ , replace CCT by 9300.
4. Use formulas 5(3.3.4) and 6(3.3.4) in Wyszecki and Stiles (pp.145-146 second edition) to compute the point (xd, yd) associated with CCT.
  - First, define  $u = 1000/CCT$ .
  - If  $CCT < 7000$ , then  $xd = -4.6070 u^3 + 2.9678 u^2 + 0.09911 u + 0.244063$ .
  - If  $CCT > 7000$ , then  $xd = -2.0064 u^3 + 1.9018 u^2 + 0.24748 u + 0.237040$ .
  - In either case,  $yd = -3.000 xd^2 + 2.870 xd - 0.275$ .
5. Convert (x, y) and (xd, yd) to  $u'v'$  coordinates:
  - $(u', v') = (4x, 9y) / (3 + 12y - 2x)$
  - $(u'd, v'd) = (4xd, 9yd) / (3 + 12yd - 2xd)$
6. Evaluate  $\Delta u'v'$  between (u,v) and (ud,vd):
  - $\Delta u'v' = \sqrt{(u' - u'd)^2 + (v' - v'd)^2}$ .
7. If  $\Delta u'v'$  is greater than 0.01, display fails the test. Otherwise it passes the test.



**Figure II.5-1** CCTs of measured whitepoints are within the boundaries required by IEC.

**Table II.5-1**  $\Delta u'v'$  Distances between measured whitepoints and CIE coordinate values from  $D_{65}$  to  $D_{93}$ .

	<u>1600 x 1200</u>
CIE x	0.310
CIE y	0.313
CIE $u'$	0.202
CIE $v'$	0.459
CCT	6808
$\Delta u'v'$	0.008

## II.6. Bit Depth

*Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.6, p 6.*

*Positive increases in luminance were measured for each of the 256 input levels for 8 bits of gray scale. Neither black level clipping nor white level saturation was observed.*

Objective: Measure the number of bits of data that can be displayed as a function of the DAC and display software.

Equipment: Photometer

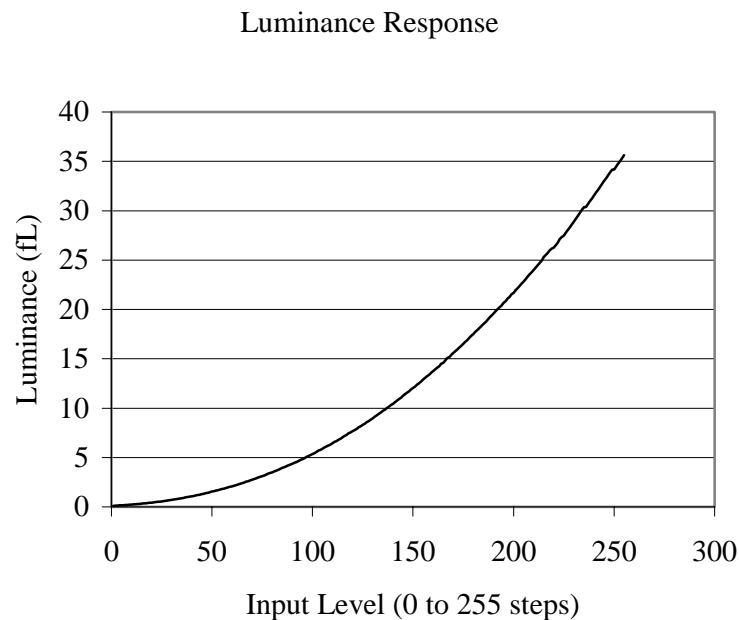
**Test targets:** Targets are n four inch patches with command levels of all commandable levels; e.g., 256 for 8 bit display. Background is commanded to  $0.5 * ((0.7 * P) + 0.3 * n)$  where P = patch command level, n = number of command levels.

**Procedure:** Measure patch center for all patches with Lmin and Lmax as defined previously. Count number of monotonically increasing luminance levels. Use the NEMA/DICOM P817 to define discriminable luminance differences. For color displays, measure white values.

**Data:** Define bit depth by  $\log_2$  (number of discrete luminance levels)

The number of bits of data that can be displayed as a function of the input signal voltage level were verified through measurements of the luminance of white test targets displayed using a Quantum Data 8701 test pattern generator and a Minolta CA-100 colorimeter. Targets are n four-inch patches with command levels of all commandable levels; e.g., 256 for 8 bit display. Background is commanded to  $0.5 * ((0.7 * P) + 0.3 * n)$  where P = patch command level, n = number of command levels. The NEMA/DICOM P817 was used to define discriminable luminance differences in JNDs.

Figure II.6-1 shows the System Tonal Transfer curve at center screen as a function of input counts. The data for each of the 256 levels are listed in Tables II.6-1 and II.6-2.



**Figure II.6-1.** System Tonal Transfer at center screen as a function of input counts.

**Table II.6-1. System Tonal Transfer at center screen as a function of input counts.**  
Target levels 000 to 127.

Back Ground	Target	L, fL	Diff, fL	Diff, JND	Back Ground	Target	L, fL	Diff, fL	Diff, JND
38	0	0.102	0.000	2	61	64	2.34	0.064	2
39	1	0.111	0.009	3	61	65	2.41	0.064	3
39	2	0.123	0.012	2	62	66	2.47	0.067	2
39	3	0.134	0.012	3	62	67	2.55	0.076	3
40	4	0.146	0.012	2	62	68	2.61	0.058	2
40	5	0.158	0.012	3	63	69	2.68	0.070	2
41	6	0.172	0.015	3	63	70	2.75	0.070	2
41	7	0.184	0.012	2	63	71	2.82	0.073	2
41	8	0.198	0.015	3	64	72	2.89	0.067	2
42	9	0.213	0.015	2	64	73	2.98	0.090	3
42	10	0.228	0.015	3	64	74	3.04	0.058	2
42	11	0.245	0.018	3	65	75	3.12	0.088	2
43	12	0.263	0.018	2	65	76	3.18	0.058	2
43	13	0.280	0.018	3	65	77	3.27	0.088	3
43	14	0.298	0.018	3	66	78	3.36	0.088	2
44	15	0.318	0.020	3	66	79	3.44	0.088	2
44	16	0.342	0.023	2	66	80	3.50	0.058	2
44	17	0.362	0.020	3	67	81	3.59	0.088	2
45	18	0.385	0.023	3	67	82	3.68	0.088	2
45	19	0.409	0.023	2	67	83	3.77	0.088	3
45	20	0.429	0.020	3	68	84	3.85	0.088	2
46	21	0.455	0.026	3	68	85	3.94	0.088	2
46	22	0.482	0.026	2	69	86	4.03	0.088	2
46	23	0.508	0.026	3	69	87	4.12	0.088	2
47	24	0.531	0.023	2	69	88	4.20	0.088	2
47	25	0.560	0.029	3	70	89	4.29	0.088	2
48	26	0.590	0.029	3	70	90	4.38	0.088	2
48	27	0.619	0.029	2	70	91	4.47	0.088	2
48	28	0.648	0.029	3	71	92	4.55	0.088	2
49	29	0.680	0.032	2	71	93	4.64	0.088	2
49	30	0.709	0.029	3	71	94	4.76	0.117	2
49	31	0.744	0.035	3	72	95	4.85	0.088	2
50	32	0.776	0.032	2	72	96	4.93	0.088	2
50	33	0.811	0.035	3	72	97	5.05	0.117	2
50	34	0.847	0.035	2	73	98	5.17	0.117	2
51	35	0.884	0.038	3	73	99	5.25	0.088	2
51	36	0.919	0.035	2	73	100	5.34	0.088	2
51	37	0.957	0.038	3	74	101	5.46	0.117	2
52	38	0.995	0.038	2	74	102	5.58	0.117	2
52	39	1.04	0.041	3	74	103	5.69	0.117	2
52	40	1.08	0.041	2	75	104	5.78	0.088	2
53	41	1.12	0.041	3	75	105	5.90	0.117	2
53	42	1.16	0.041	2	76	106	6.01	0.117	2
53	43	1.20	0.044	3	76	107	6.13	0.117	2
54	44	1.25	0.044	2	76	108	6.22	0.088	2
54	45	1.29	0.044	2	77	109	6.33	0.117	2
55	46	1.33	0.044	3	77	110	6.45	0.117	1
55	47	1.39	0.053	3	77	111	6.57	0.117	2
55	48	1.44	0.053	2	78	112	6.68	0.117	2
56	49	1.49	0.050	3	78	113	6.80	0.117	2
56	50	1.54	0.053	2	78	114	6.92	0.117	2
56	51	1.59	0.050	3	79	115	7.06	0.146	2
57	52	1.64	0.053	2	79	116	7.18	0.117	2
57	53	1.69	0.050	2	79	117	7.30	0.117	2
57	54	1.75	0.055	3	80	118	7.44	0.146	2
58	55	1.80	0.055	2	80	119	7.56	0.117	2
58	56	1.86	0.058	2	80	120	7.68	0.117	1
58	57	1.91	0.053	3	81	121	7.79	0.117	2
59	58	1.97	0.058	2	81	122	7.91	0.117	2
59	59	2.03	0.061	2	81	123	8.06	0.146	2
59	60	2.09	0.055	3	82	124	8.17	0.117	1
60	61	2.15	0.061	2	82	125	8.29	0.117	2
60	62	2.21	0.058	2	83	126	8.44	0.146	2
60	63	2.28	0.067	2	83	127	8.58	0.146	2

*Use or disclosure of data on this sheet is subject to the restrictions on the cover and title of this report.*

**Table II.6-2.** System Tonal Transfer at center screen as a function of input counts  
Target levels 128 to 255.

Back ground	Target	L, fL	Diff, fL	Diff, JND	Back ground	Target	L, fL	Diff, fL	Diff, JND
83	128	8.70	0.117	1	106	192	20.0	0.204	2
84	129	8.84	0.146	2	106	193	20.2	0.234	1
84	130	8.99	0.146	2	106	194	20.4	0.175	1
84	131	9.14	0.146	2	107	195	20.6	0.234	2
85	132	9.28	0.146	2	107	196	20.8	0.204	1
85	133	9.43	0.146	1	107	197	21.1	0.263	2
85	134	9.57	0.146	2	108	198	21.3	0.175	1
86	135	9.72	0.146	2	108	199	21.5	0.234	1
86	136	9.87	0.146	2	108	200	21.7	0.175	1
86	137	10.0	0.146	1	109	201	22.0	0.263	2
87	138	10.2	0.146	2	109	202	22.2	0.204	1
87	139	10.3	0.146	2	109	203	22.4	0.234	1
87	140	10.5	0.146	1	110	204	22.6	0.234	2
88	141	10.6	0.146	2	110	205	22.8	0.204	1
88	142	10.8	0.175	2	111	206	23.1	0.234	1
88	143	10.9	0.146	1	111	207	23.3	0.263	2
89	144	11.1	0.146	2	111	208	23.6	0.234	1
89	145	11.2	0.175	2	112	209	23.8	0.204	1
90	146	11.4	0.175	2	112	210	24.0	0.263	1
90	147	11.6	0.146	1	112	211	24.3	0.234	2
90	148	11.7	0.146	2	113	212	24.5	0.204	1
91	149	11.9	0.175	1	113	213	24.7	0.234	1
91	150	12.1	0.175	2	113	214	25.0	0.263	1
91	151	12.2	0.146	1	114	215	25.3	0.350	2
92	152	12.4	0.175	2	114	216	25.5	0.204	1
92	153	12.5	0.146	2	114	217	25.7	0.204	1
92	154	12.7	0.175	1	115	218	26.0	0.292	2
93	155	12.9	0.204	2	115	219	26.2	0.146	1
93	156	13.0	0.146	2	115	220	26.3	0.117	0
93	157	13.2	0.175	1	116	221	26.5	0.234	1
94	158	13.4	0.175	2	116	222	26.8	0.263	2
94	159	13.6	0.175	1	116	223	27.1	0.350	1
94	160	13.7	0.175	2	117	224	27.3	0.204	1
95	161	13.9	0.175	1	117	225	27.5	0.175	1
95	162	14.1	0.175	2	118	226	27.8	0.292	2
95	163	14.2	0.146	1	118	227	28.1	0.263	1
96	164	14.5	0.234	2	118	228	28.3	0.292	1
96	165	14.6	0.117	1	119	229	28.6	0.292	2
97	166	14.8	0.234	2	119	230	28.9	0.234	1
97	167	15.1	0.234	2	119	231	29.2	0.292	1
97	168	15.2	0.117	1	120	232	29.5	0.321	2
98	169	15.4	0.204	2	120	233	29.8	0.292	1
98	170	15.6	0.204	1	120	234	30.1	0.292	1
98	171	15.8	0.175	2	121	235	30.4	0.292	2
99	172	15.9	0.175	1	121	236	30.4	0.000	0
99	173	16.1	0.204	2	121	237	30.6	0.292	1
99	174	16.3	0.175	1	122	238	30.9	0.292	1
100	175	16.5	0.204	2	122	239	31.2	0.292	1
100	176	16.7	0.204	1	122	240	31.5	0.292	2
100	177	16.9	0.175	1	123	241	31.8	0.292	1
101	178	17.1	0.204	2	123	242	32.1	0.292	1
101	179	17.3	0.234	2	123	243	32.4	0.292	1
101	180	17.5	0.175	1	124	244	32.7	0.292	2
102	181	17.7	0.204	1	124	245	33.0	0.292	1
102	182	17.9	0.204	2	125	246	33.3	0.292	1
102	183	18.1	0.204	1	125	247	33.6	0.292	1
103	184	18.3	0.175	1	125	248	33.9	0.292	1
103	185	18.5	0.204	2	126	249	34.2	0.292	1
104	186	18.7	0.204	1	126	250	34.2	0.000	0
104	187	18.9	0.234	2	126	251	34.4	0.292	2
104	188	19.1	0.204	1	127	252	34.7	0.292	1
105	189	19.4	0.234	2	127	253	35.0	0.292	1
105	190	19.6	0.204	1	127	254	35.3	0.292	1
105	191	19.8	0.204	1	128	255	35.6	0.292	1

## II.8. Luminance Step Response

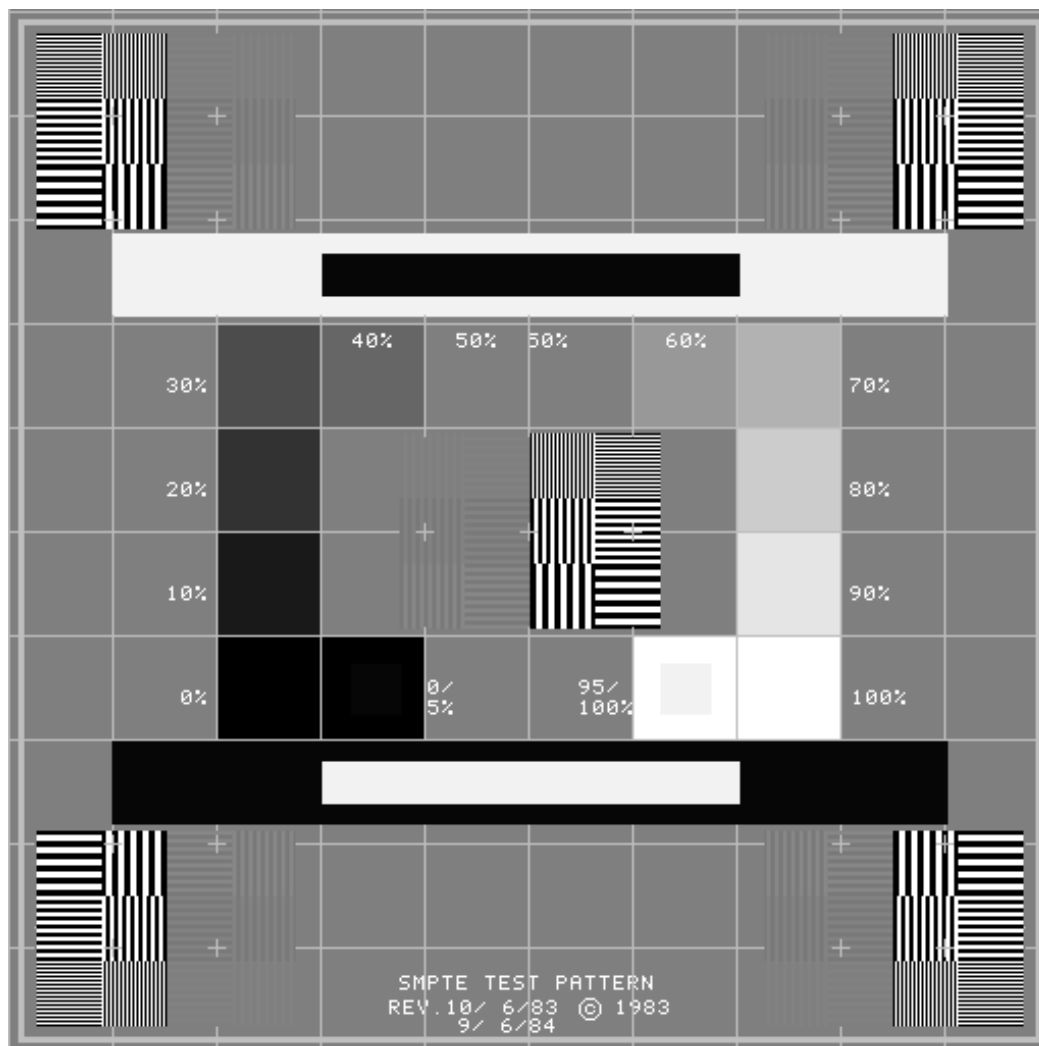
*Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.8, p 7.*

*No video artifacts were observed.*

**Objective:** Determine the presence of artifacts caused by undershoot or overshoot.

**Equipment:** Test targets, SMPTE Test Pattern RP-133-1991, 2-D CCD array

**Procedure:** Display a center box 15% of screen size at input count levels corresponding to 25%, 50%, 75%, and 100% of Lmax with a surround of count level 0. Repeat using SMPTE Test pattern



**Figure II.8-1.** SMPTE Test Pattern.

Data: Define passes by absence of noticeable ringing, undershoot, overshoot, or streaking.

The test pattern shown in Figure II.8-1 was used in the visual evaluation of the monitor. This test pattern is defined in SMPTE Recommended Practice RP-133-1986 published by the Society of Motion Picture and Television Engineers (SMPTE) for medical imaging applications. Referring to the large white-in-black and black-in-white horizontal bars contained in the test pattern, RP133-1986, paragraph 2.7 states “ These areas of maximum contrast facilitate detection of mid-band streaking (poor low-frequency response), video amplifier ringing or overshoot, deflection interference, and halo.” None of these artifacts was observed in the Viewsonic P817 monitor, signifying good electrical performance of the video circuits.

## II.9. Addressability

*Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.1, page 67.*

*This monitor properly displayed all addressed pixels for the following tested format (HxV):  
1600 x 1200 x 72 Hz, 1024 x 1024 x 120 Hz.*

Objective: Define the number of addressable pixels in the horizontal and vertical dimension; confirm that stated number of pixels is displayed.

Equipment: Programmable video signal generator.  
Test pattern with pixels lit on first and last addressable rows and columns and on two diagonal lines beginning at upper left and lower right; H & V grill patterns 1-on/1-off.

Procedure: The number of addressed pixels were programmed into the Quantum Data 8701 test pattern generator for 72 Hz minimum for monoscopic mode and 120 Hz minimum for stereoscopic mode, where possible. All perimeter lines were confirmed to be visible, with no irregular jaggies on diagonals and, for monochrome monitors, no strongly visible moiré on grilles.

Data: If tests passed, number of pixels in horizontal and vertical dimension. If test fails, addressability unknown.

**Table II.9-1** Addressabilities Tested

Monoscopic Mode	Stereo Mode
1600 x 1200	1024 x 1024



## II.10. Pixel Aspect Ratio

*Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.10, p 8.*

*Pixel aspect ratio is within 0.4%.*

Objective: Characterize aspect ratio of pixels.

Equipment: Test target, measuring tape with at least 1/16th inch increments

Procedure: Display box of 400 x 400 pixels at input count corresponding to 50% Lmax and background of 0. Measure horizontal and vertical dimension.

Alternatively, divide number of addressable pixels by the total image size to obtain nominal pixel spacings in horizontal and vertical directions.

Data: Define pass if  $H = V \pm 6\%$  for pixel density <100 ppi and  $\pm 10\%$  for pixel density > 100 ppi.

	<b>Monoscopic Mode</b>
Addressability (H x V)	<b>1280 x 1024</b>
H x V Image Size (inches)	15.656 x 11.705
H x V Pixel Spacing (mils)	9.79 x 9.75
H x V Pixel Aspect Ratio	$H = V + 0.4\%$

## II.11. Screen Size (Viewable Active Image)

*Reference: VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998, Section 501-1.*

*Image size as tested in monoscopic mode (1600 x 1200) was 19.548 inches in diagonal.*

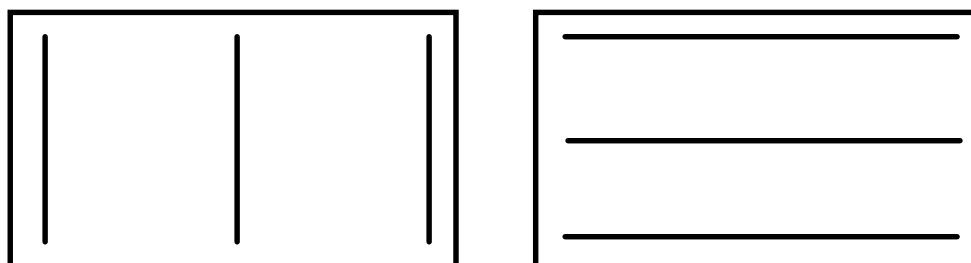
Objective: Measure beam position on the CRT display to quantify width and height of active image size visible by the user (excludes any overscanned portion of an image).

Equipment:

- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.11-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern are displayed at 100% L<sub>max</sub> must be

positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



1-pixel-wide lines displayed at 100%  $L_{\max}$

**Figure II.11-1** Three-line grille test patterns.

**Procedure:** Use diode optic module to locate center of line profiles in conjunction with calibrated X-Y translation to measure screen x, y coordinates of lines at the ends of the major and minor axes.

**Data:** Compute the image width defined as the average length of the horizontal lines along the top, bottom and major axis of the screen. Similarly, compute the image height defined as the average length of the vertical lines along the left side, right side, and minor axis of the screen. Compute the diagonal screen size as the square-root of the sum of the squares of the width and height.

**Table II.11-1.** Image Size

	<b>Monoscopic Mode</b>
Addressability (H x V)	<b>1600 x 1200</b>
H x V Image Size (inches)	15.656 x 11.705
Diagonal Image Size (inches)	19.548

## II.12. Contrast Modulation

*Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 5.2, page 57.*

*Contrast modulation (Cm) for 1-on/1-off grille patterns displayed at 50% Lmax exceeded Cm = 29% in Zone A, and exceeded Cm = 40% in Zone B.*

**Objective:** Quantify contrast modulation as a function of screen position.

**Equipment:**

- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Photometer with linearized response

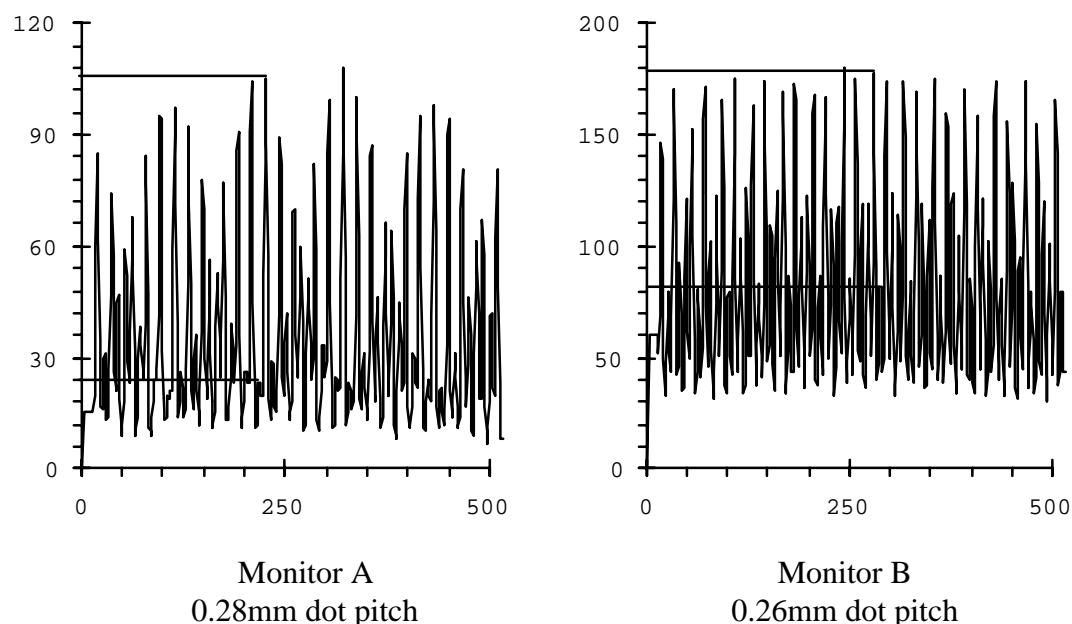
**Procedure:** The maximum video modulation frequency for each format (1280 x 1024, 1600 x 1200) was examined using horizontal and vertical grille test patterns consisting of alternating lines with 1 pixel on, 1 pixel off. Contrast modulation was measured in both horizontal and vertical directions at screen center and at eight peripheral screen positions. The measurements should be along the horizontal and vertical axes and along the diagonal from these axes. Use edge measurements no more than 10% of screen size in from border of active screen. The input signal level was set so that 1-line-on/1-line-off horizontal grille patterns produced a screen area-luminance of 25% of maximum level, Lmax.

Zone A is defined as a 24 degree subtended circle from a viewing distance of 18 inches (7.6 inch circle). Zone B is the remainder of the display. Use edge measurements no more than 10% of screen size in from border of active screen area to define Cm for Zone B (remaining area outside center circle). Determine Cm at eight points on circumference of circle by interpolating between center and display edge measurements to define Cm for Zone A. If measurements exceed the threshold, do not make any more measurements. If one or more measurements fail the threshold, make eight additional measurements at the edge (but wholly within) the defined circle.

**Data:** Values of vertical and horizontal Cm for Zone A and Zone B are given in Table II.12-1. The contrast modulation, Cm, is reported (the defining equation is given below) for the 1-on/1-off grille patterns. The modulation is equal to or greater than 51% in Zone A, and is equal to or greater than 35% in Zone B.

$$C_m = \frac{L_{\text{peak}} - L_{\text{valley}}}{L_{\text{peak}} + L_{\text{valley}}}$$

The sample contrast modulations shown in Figure II.12-1 for two different color CRTs are not fully realized because of the presence of moiré caused by aliasing between the image and the shadowmask. Because contrast modulation values are calculated for the maximum peak and minimum valley luminance levels as indicated in the sample data shown, they do not include the degrading effects of aliasing.



**Figure II.12-1.** Contrast modulation for sample luminance profiles (1 pixel at input level corresponding to 50%  $L_{max}$ , 1 pixel at level  $0 = L_{min}$ ) for monitors exhibiting moiré due to aliasing.

**Table II.12-1. Contrast Modulation**  
Corrected for lens flare and Zone Interpolation

Zone A = 7.6-inch diameter circle for 24-degree subtended at 18-inch viewing distance								
	Left		Minor				Right	
	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille
Top	76%	48%			77%	55%		79% 43%
Major	89% 47%		48% 48%		60% 53%		49% 47%	87% 40%
			58% 48%		29% 49%		57% 45%	
			49% 48%		61% 53%		51% 46%	
Bottom	79%	46%			78%	55%		86% 40%

Zone A = 9.66-inch diameter circle for 40% area								
	Left		Minor				Right	
	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille
Top	76%	48%			77%	55%		79% 43%
Major	89% 47%		52% 48%		69% 54%		54% 46%	87% 40%
			66% 48%		29% 49%		65% 44%	
			54% 47%		70% 54%		57% 45%	
Bottom	79%	46%			78%	55%		86% 40%

Use or disclosure of data on this sheet is subject to the restrictions on the cover and title of this report.

## II.13. Pixel Density

*Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.13, p 9.*

*Pixel density was 102H x 103V pixels per inch (ppi) as tested for the 1600 x 1200-line format.*

Objective: Characterize density of image pixels

Equipment: Measuring tape with at least 1/16 inch increments

Procedure: Measure H&V dimension of active image window and divide by vertical and horizontal addressability

Data: Define horizontal and vertical pixel density in terms of pixels per inch

**Table II.13-1. Pixel-Density**

	<b>Monoscopic Mode</b>
H x V Addressability, Pixels	<b>1600 x 1200</b>
H x V Image Size, Inches	15.656 x 11.705
H x V Pixel Density, ppi	102 x 103

## II.14. Moiré

*Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.14, p 9.*

*Phosphor-to-pixel spacing ratios are less than 1.0 for the 1600 x 1200 format (horizontal ratio = 0.89). Compensation circuitry effectively reduces the visibility of moiré patterns when displaying 1-on/1-off vertical grille patterns.*

Objective: Determine lack of moiré.

Equipment Loupe with scale graduated in 0.001 inch or equivalent

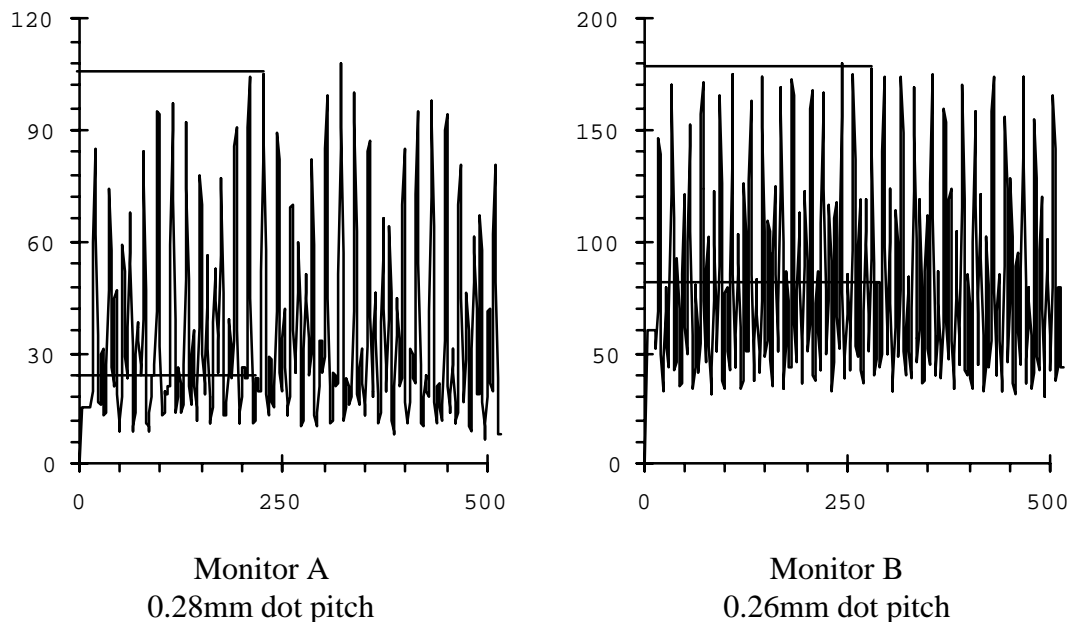
Procedure Measure phosphor pitch in vertical and horizontal dimension at screen center. For aperture grille screens, vertical pitch will be 0. Define pixel size by 1/pixel density.

Data: Define value of phosphor: pixel spacing. Value <1 passes, but <0.6 preferred.

**Table II.14-1. Phosphor-to-Pixel-Spacing Ratios**

	<b>Monoscopic Mode</b>
Addressability	<b>1600 x 1200</b>
Pixel Spacing (H x V)	9.79 x 9.75 mils
Phosphor Pitch (Diagonal)	0.26 mm
(H x V)	0.22 mm x 0.13 mm
Phosphor-to-Pixel-Spacing	0.89 x 0.52

Discussion: Moiré occurs when the phosphor pitch is too large in comparison to the pixel size. Studies have shown that a phosphor pitch of about 0.6 pixels or less is required for adequate visibility of image information without interference from the phosphor structure.



**Figure II.12-1.** Contrast modulation for sample luminance profiles (1 pixel at level 50, 1 pixel at level 0) for monitors exhibiting moiré due to aliasing.

In Figure II.12-1, Monitor A phosphor pitch is 0.90 pixels as compared with 0.84 pixels in Monitor B. Moiré is more visible in Monitor A, appearing as long stripes where contrast modulation has been degraded. In Monitor B, moiré is less visible, appearing as "fish-scales" where contrast modulation has been reduced. Even though the Monitor A exhibits a greater loss of contrast modulation from the presence of moiré on 1-on/1-off vertical grille patterns, there is little or no visual impact when aerial photographic images are displayed. NIDL experts in human vision and psychophysics were unable to discern presence of moiré on either monitor when grayscale imagery was displayed.

## II.15. Straightness

*Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.1 Waviness, page 67.*

*Waviness, a measure of straightness, did not exceed 0.45% of the total image height or width.*

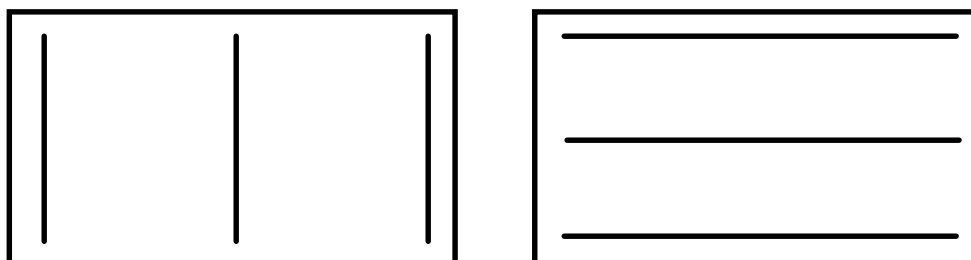
**Objective:** Measure beam position on the CRT display to quantify effects of waviness which causes nonlinearities within small areas of the display distorting nominally straight features in images, characters, and symbols.

**Equipment:**

- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

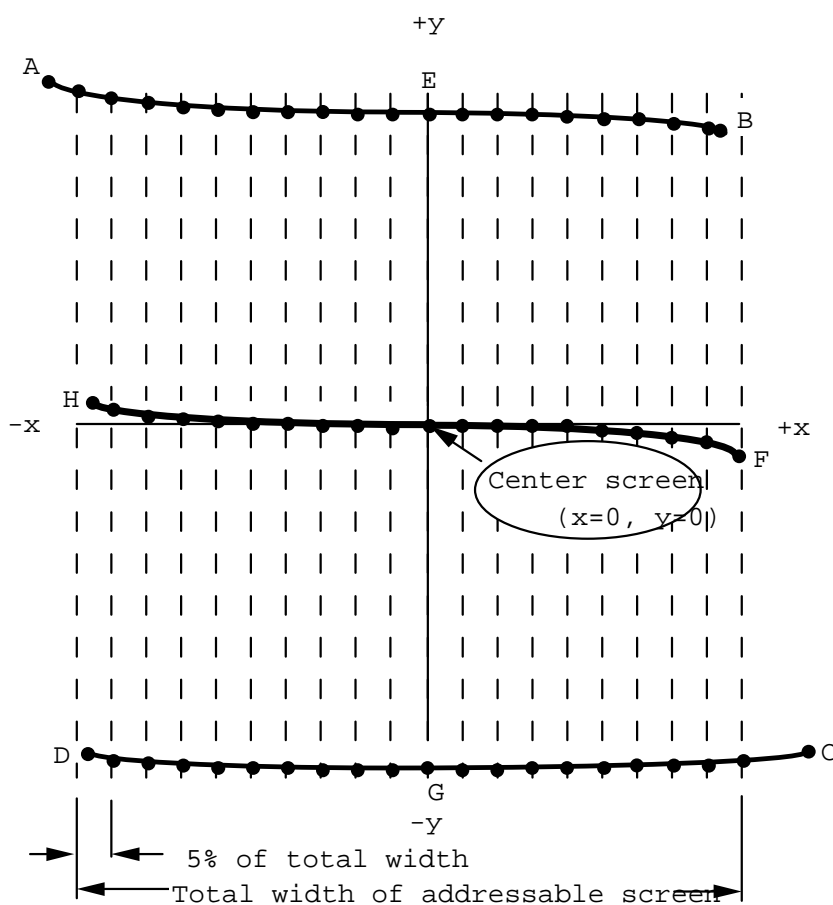
*Use or disclosure of data on this sheet is subject to the restrictions on the cover and title of this report.*

**Test Pattern:** Use the three-line grille patterns in Figure II.15-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern are displayed at 100%  $L_{\max}$  must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



1-pixel-wide lines displayed at 100%  $L_{\max}$

**Figure II.15-1** Three-line grille test patterns.



**Figure II.15-2** Measurement locations for waviness along horizontal lines. Points A, B, C, D are extreme corner points of addressable screen. Points E, F, G, H are the endpoints of the axes.

*Use or disclosure of data on this sheet is subject to the restrictions on the cover and title of this report.*



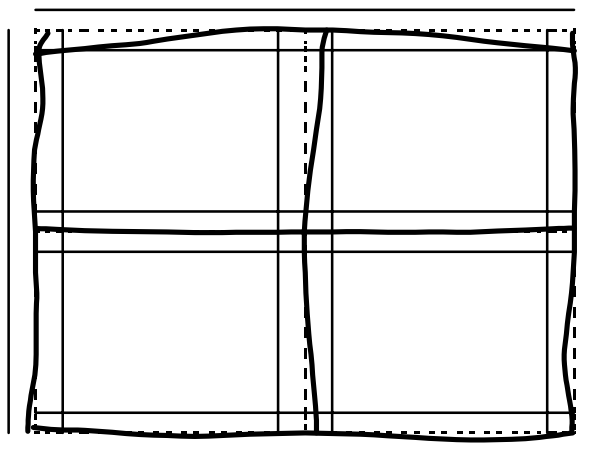
**Procedure:** Use diode optic module to locate center of line profiles in conjunction with calibrated X-Y translation to measure screen x, y coordinates along the length of a nominally straight line. Measure x, y coordinates at 5% addressable screen intervals along the line. Position vertical lines in video to land at each of three (3) horizontal screen locations for determining waviness in the horizontal direction. Similarly, position horizontal lines in video to land at each of three (3) vertical screen locations for determining waviness in the vertical direction.

**Data:** Tabulate x, y positions at 5% addressable screen increments along nominally straight lines at top and bottom, major and minor axes, and left and right sides of the screen as shown in Table II.15-I. Figure II.15-3 shows the results in graphical form.

**Table II.15-1. Straightness**

Tabulated x, y positions at 5% addressable screen increments along nominally straight lines.

Top		Bottom		Major		Minor		Left Side		Right Side	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
-7831	5849	-7896	-5874	-7829	10	60	5908	-7818	5812	7884	5815
-7200	5857	-7200	-5881	-7200	8	47	5400	-7843	5400	7885	5400
-6400	5865	-6400	-5883	-6400	4	46	4800	-7841	4800	7892	4800
-5600	5873	-5600	-5888	-5600	2	44	4200	-7834	4200	7888	4200
-4800	5880	-4800	-5895	-4800	1	39	3600	-7834	3600	7886	3600
-4000	5893	-4000	-5898	-4000	0	30	3000	-7845	3000	7888	3000
-3200	5904	-3200	-5900	-3200	-2	22	2400	-7857	2400	7890	2400
-2400	5915	-2400	-5898	-2400	-2	12	1800	-7860	1800	7891	1800
-1600	5922	-1600	-5894	-1600	-1	5	1200	-7861	1200	7891	1200
-800	5923	-800	-5892	-800	-1	-1	600	-7858	600	7889	600
0	5919	0	-5890	0	0	-5	0	-7854	0	7889	0
800	5919	800	-5892	800	0	-5	-600	-7854	-600	7889	-600
1600	5914	1600	-5894	1600	1	-3	-1200	-7854	-1200	7886	-1200
2400	5912	2400	-5899	2400	-1	-1	-1800	-7851	-1800	7881	-1800
3200	5909	3200	-5903	3200	-1	3	-2400	-7852	-2400	7873	-2400
4000	5902	4000	-5908	4000	0	8	-3000	-7852	-3000	7866	-3000
4800	5892	4800	-5911	4800	-1	14	-3600	-7852	-3600	7860	-3600
5600	5882	5600	-5910	5600	3	19	-4200	-7856	-4200	7863	-4200
6400	5873	6400	-5907	6400	6	24	-4800	-7867	-4800	7873	-4800
7200	5866	7200	-5899	7200	9	29	-5400	-7875	-5400	7882	-5400
7821	5858	7776	-5890	7816	11	30	-5898	-7877	-5849	7882	-5834

**1600 x 1200**

**Figure II.15-3** Waviness of Viewsonic P817 Color monitor in 1600 x 1200 mode. Departures from straight lines are exaggerated on a 10X scale. Error bars are +/- 0.5% of total screen size.

## II.16. Refresh Rate

*Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.16, p 9.*

*Vertical refresh rate for 1600 x 1200 format was set to 72 Hz, and not limited by the monitor.*

*Vertical refresh rate for the 1024 x 1024 stereo format was set to 120 Hz.*

**Objective:** Define vertical and horizontal refresh rates.

**Equipment:** Programmable video signal generator.

**Procedure:** The refresh rates were programmed into the Quantum Data 8701 test pattern generator for 72 Hz minimum for monoscopic mode and 120 Hz minimum for stereoscopic mode, where possible.

**Data:** Report refresh rates in Hz.

**Table II.16-1** Refresh Rates as Tested

	<b>Monoscopic Mode</b>	<b>Stereo Mode</b>
<b>Addressability</b>	<b>1600 x 1200</b>	<b>1024 x 1024</b>
<b>Vertical Scan</b>	72 Hz	120 Hz
<b>Horizontal Scan</b>	88.9 kHz	129.9 kHz

## II.17. Extinction Ratio

*Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.17, p10.*

*Stereo extinction ratio averaged 10.5 to 1 (10.0 left, 11.0 right) at screen center. Luminance of white varied by up to 17% across the screen. Chromaticity variations of white were less than 0.008 delta u'v' units.*

Objective: Measure stereo extinction ratio

Equipment: Two “stereo” pairs with full addressability. One pair has left center at command level of 255 (or Cmax) and right center at 0. The other pair has right center at command level of 255 (or Cmax) and left center at 0.

Stereoscopic-mode measurements were made using a commercially-available Nuvision 19-inch LCD shutter with passive polarized eyeglasses.

Procedure: Calibrate monitor to 0.1 fL Lmin and 35 fL Lmax (no ambient). Measure ratio of Lmax to Lmin on both left and right side images through the stereo system.

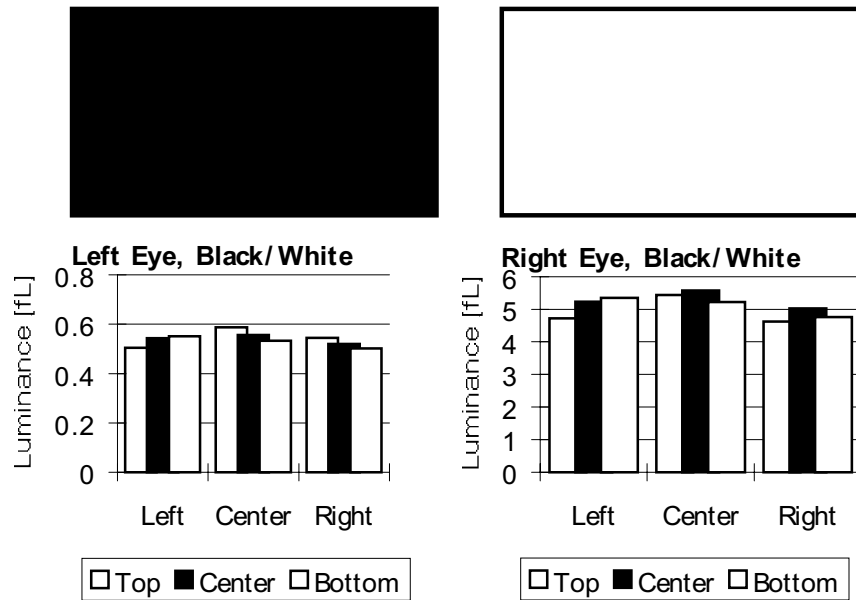
Data: Extinction ratio (left) =  $L(\text{left, on, white/black}) / L(\text{left, off, black/white})$

$L(\text{left, on, white/black}) \sim \text{trans}(\text{left, on}) * \text{trans}(\text{stereo}) * L(\text{max}) * \text{Duty}(\text{left})$   
 $+ \text{trans}(\text{left, off}) * \text{trans}(\text{stereo}) * L(\text{min}) * \text{Duty}(\text{right})$   
 Use left, off/right, on to perform this measurement

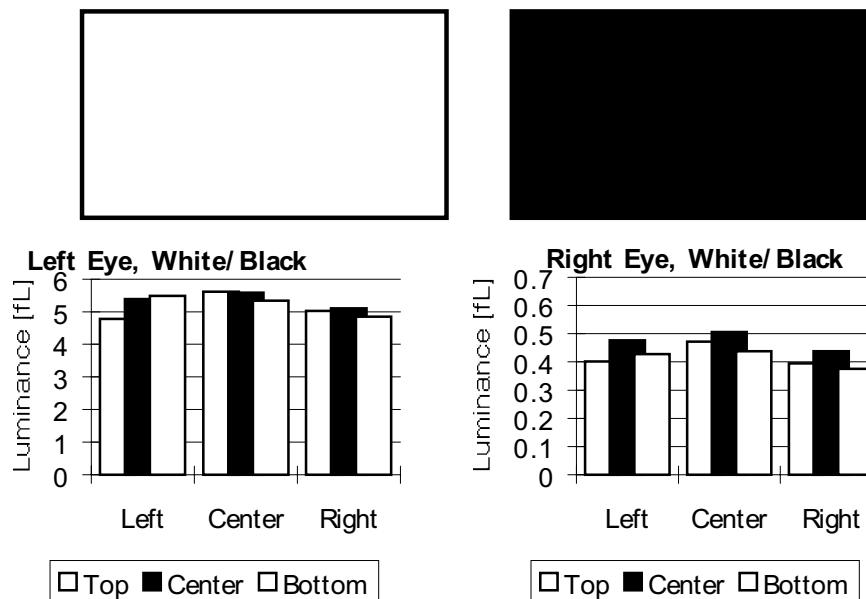
Extinction ratio (right) =  $L(\text{right, on, white/black}) / L(\text{right, off, black/white})$

$L(\text{right, on, white/black}) \sim$   
 $\text{trans}(\text{right, on}) * \text{trans}(\text{stereo}) * L(\text{max}) * \text{Duty}(\text{right})$   
 $+ \text{trans}(\text{right, off}) * \text{trans}(\text{stereo}) * L(\text{min}) * \text{Duty}(\text{left})$   
 Use left, on/right, off to perform this measurement

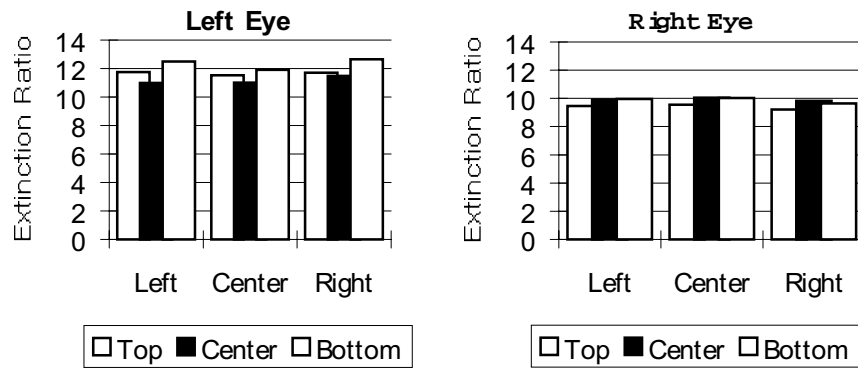
Stereo extinction ratio is average of left and right ratios defined above.



**Fig.II.17-1.** Spatial Uniformity of luminance in stereo mode when displaying black to the left eye while displaying white to the right eye.



**Fig.II.17-2.** Spatial Uniformity of luminance in stereo mode when displaying white to the left eye while displaying black to the right eye.



**Fig.II.17-3.** Spatial Uniformity of extinction ratio in stereo mode.



**Fig.II.17-4** Spatial Uniformity of chromaticity of white in stereo mode.

## II.18. Linearity

*Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.2, page 73.*

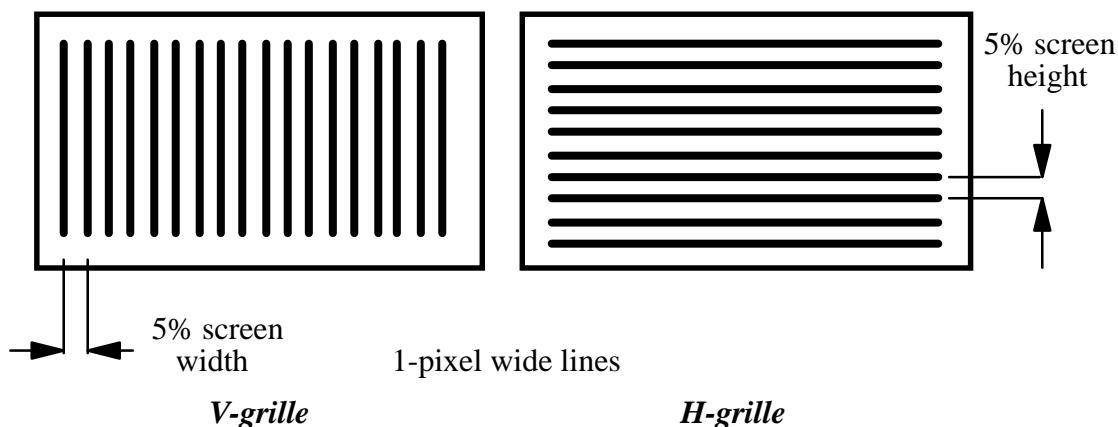
*The maximum nonlinearity of the scan was 0.88% of full screen.*

**Objective:** Measure the relation between the actual position of a pixel on the screen and the commanded position to quantify effects of raster nonlinearity. Nonlinearity of scan degrades the preservation of scale in images across the display.

**Equipment:**

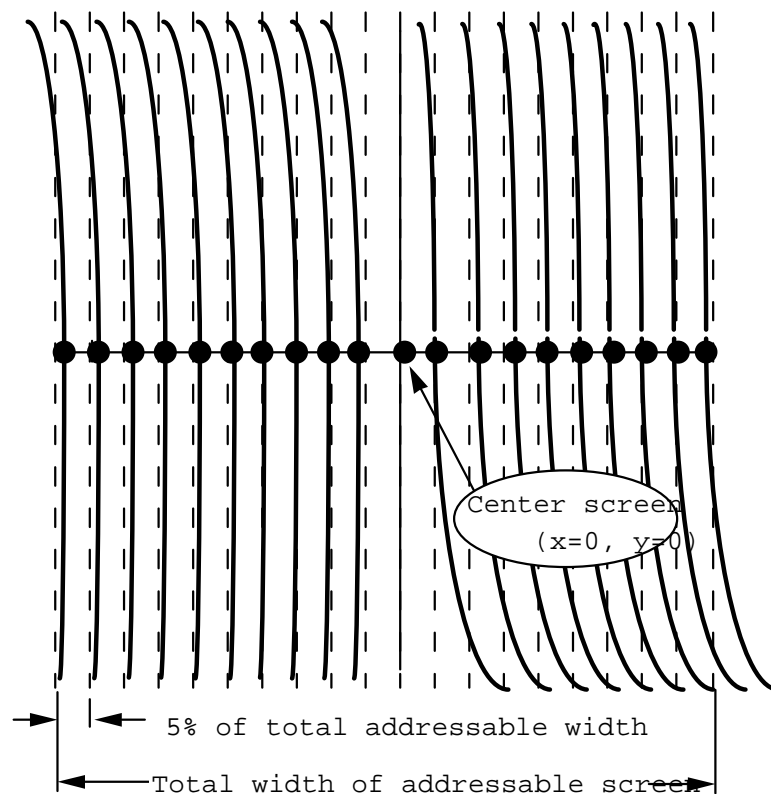
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

**Test Pattern:** Use grille patterns of single-pixel horizontal lines and single-pixel vertical lines displayed at 100%  $L_{max}$ . Lines are equally spaced in addressable pixels. Spacing must be constant and equal to approximately 5% screen width and height to the nearest addressable pixel as shown in Figure II.18-1.



**Figure II.18-1.** *Grille patterns for measuring linearity*

**Procedure:** The linearity of the raster scan is determined by measuring the positions of lines on the screen. Vertical lines are measured for the horizontal scan, and horizontal lines for the vertical scan. Lines are commanded to 100%  $L_{max}$  and are equally spaced in the time domain by pixel indexing on the video test pattern. Use optic module to locate center of line profiles in conjunction with x, y-translation stage to measure screen x, y coordinates of points where video pattern vertical lines intersect horizontal centerline of screen and where horizontal lines intersect vertical centerline of the CRT screen as shown in Figure II.18-2.



**Figure II.18-2.** *Measurement locations for horizontal linearity along the major axis of the display. Equal pixel spacings between vertical lines in the grille pattern are indicated by the dotted lines. The number of pixels per space is nominally equivalent to 5% of the addressable screen size.*

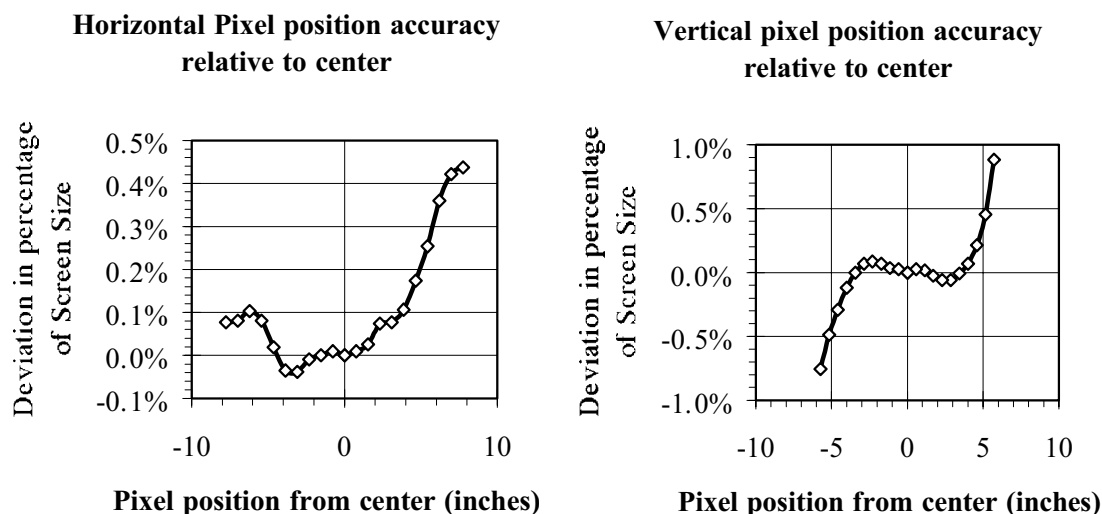
**Data:** Tabulate x, y positions of equally spaced lines (nominally 5% addressable screen apart) along major (horizontal centerline) and minor (vertical centerline) axes of the raster. If both scans were truly linear, the differences in the positions of adjacent lines would be a constant. The departures of these differences from constancy impacts the absolute position of each pixel on the screen and is, then, the nonlinearity. The degree of nonlinearity may be different between left and right and between top and bottom. The maximum horizontal and vertical nonlinearities (referred to full screen size) are listed in table II.18-1. The complete measured data are listed in table II.18-2 and shown graphically in Figure II.18-3.

**Table II.18-1. Maximum Horizontal and Vertical Nonlinearities**

Format	Left Side	Right Side	Top	Bottom
1600 x 1200	0.10%	0.44%	0.88%	0.76%

**Table II.18-2. Horizontal and Vertical Nonlinearities Data**

<b>Vertical Lines</b> <b>x-Position (mils)</b>		<b>Horizontal lines</b> <b>y-Position (mils)</b>	
<u>Left Side</u>	<u>Right Side</u>	<u>Top</u>	<u>Bottom</u>
-7733	7813	5833	-5818
-6958	7036	5210	-5214
-6180	6252	4609	-4618
-5409	5461	4019	-4025
-4644	4674	3437	-3438
-3878	3889	2858	-2857
-3104	3110	2285	-2282
-2325	2335	1716	-1711
-1549	1553	1148	-1142
-773	776	576	-570
0	0	0	0

**Fig. II.18-5** Horizontal and vertical linearity characteristics.

## II.19. Jitter/Swim/Drift

*Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 6.4, p80.*

*Maximum jitter and swim/drift were 1.9 mils and 3.0 mils, respectively.*

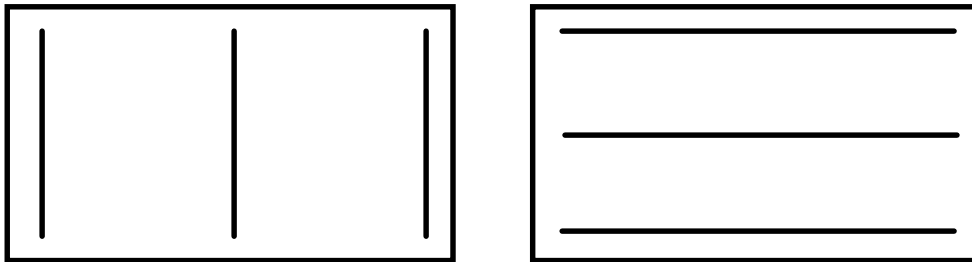
**Objective:** Measure amplitude and frequency of variations in beam spot position of the CRT display. Quantify the effects of perceptible time varying raster distortions: jitter, swim, and drift. The perceptibility of changes in the position of an image depend upon the amplitude and frequency of the motions which can be caused by imprecise control electronics or external magnetic fields.

*Use or disclosure of data on this sheet is subject to the restrictions on the cover and title of this report.*



- Equipment:
- Video generator
  - Spatially calibrated CCD or photodiode array optic module
  - Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.19-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



V-grille for measuring horizontal motion

H-grille for measuring vertical motion

1-pixel wide lines

*Three-line grille test patterns.*

**Figure II.19-1**

**Procedure:** With the monitor set up for intended scanning rates, measure vertical and horizontal line jitter (0.01 to 2 seconds), swim (2 to 60 seconds) and drift (over 60 seconds) over a 2.5 minute duration as displayed using grille video test patterns. Generate a histogram of raster variance with time. The measurement interval must be equal to a single field period.

Optionally, for multi-sync monitors measure jitter over the specified range of scanning rates. Some monitors running vertical scan rates other than AC line frequency may exhibit increased jitter.

Measure and report instrumentation motion by viewing Ronchi ruling or illuminated razor edge mounted to the top of the display. It may be necessary to mount both the optics and the monitor on a vibration damped surface to reduce vibrations.

**Data:** Tabulate motion as a function of time in x-direction at top-left corner screen location. Repeat for variance in y-direction. Tabulate maximum motions (in mils) with display input count level corresponding to  $L_{\max}$  for jitter (0.01 to 2 seconds), swim (2 to 60 seconds) and drift (over 60 seconds) over a 2.5 minute duration. The data are presented in Table II.19-1. Both the monitor and the Microvision equipment sit on a vibration-damped aluminum-slab measurement bench. The motion of the test bench was a factor of 10 times smaller than the CRT raster motion.

*Use or disclosure of data on this sheet is subject to the restrictions on the cover and title of this report.*

**Table II.19-1. Jitter/Swim/Drift**

Time scales: Jitter 2 sec., Swim 10 sec., and Drift 60 sec.

**1600 x 1200 x 72 Hz**

Signal Generator		Quantum Data FOX 8701	
<u>Position</u>		<u>H-lines</u>	<u>V-lines</u>
10D corner	Max Motions		
	Jitter	1.48	1.89
	Swim	1.75	2.24
	Drift	1.75	2.95
Center	Max Motions		
	Jitter	1.84	1.75
	Swim	1.94	1.98
	Drift	2.01	2.34

**II.20 Warm-up Period**

*Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.20, p. 10.*

*A 49 minute warm-up was necessary for luminance stability of  $L_{min} = 0.09 fL \pm 10\%$ .*

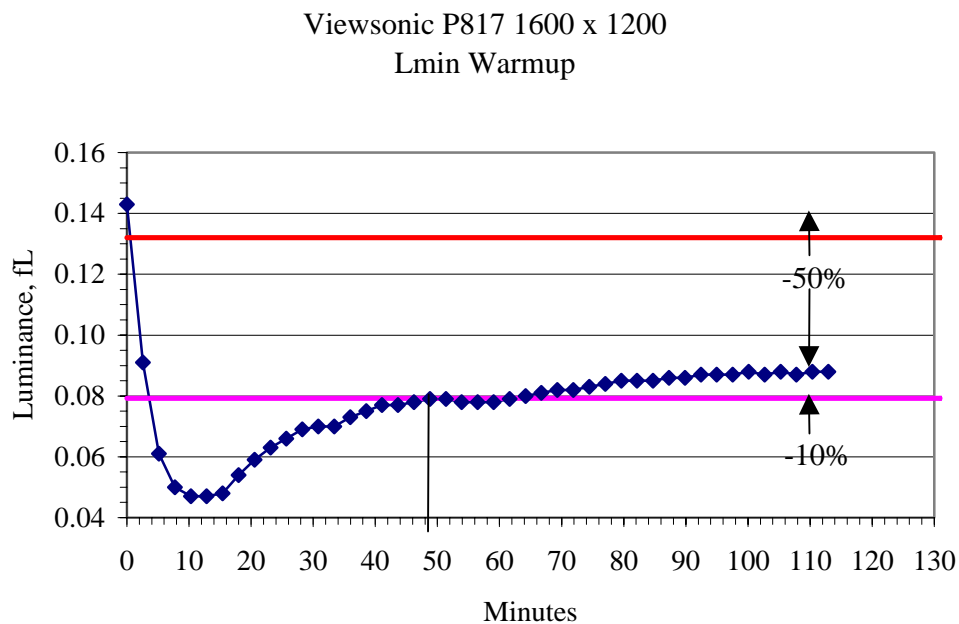
Objective: Define warm-up period

Equipment: Photometer, test target (full screen 0 count)

Procedure: Turn monitor off for three-hour period. Turn monitor on and measure center of screen luminance ( $L_{min}$  as defined in Dynamic range measurement) at 1-minute intervals for first five minutes and five minute intervals thereafter. Discontinue when three successive measurements are  $\pm 10\%$  of  $L_{min}$ .

Data: Pass if  $L_{min}$  within  $\pm 50\%$  in 30 minutes and  $\pm 10\%$  in 60 minutes.

The luminance of the screen (commanded to the minimum input level, 0 for  $L_{min}$ ) was monitored for 120 minutes after a cold start. Measurements were taken every minute. Figure II.20-1 shows the data for 1280 x 1024 format in graphical form. The luminance remains very stable after 49 minutes.



**Figure II.20.1.** Luminance (fL) as a function of time (in minutes) from a cold start with an input count of 0. (Note suppressed zero on luminance scale).